



LCDU improvement in contact-hole patterns by post treatments

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✓ **Introduction**

✓ **Metrology**

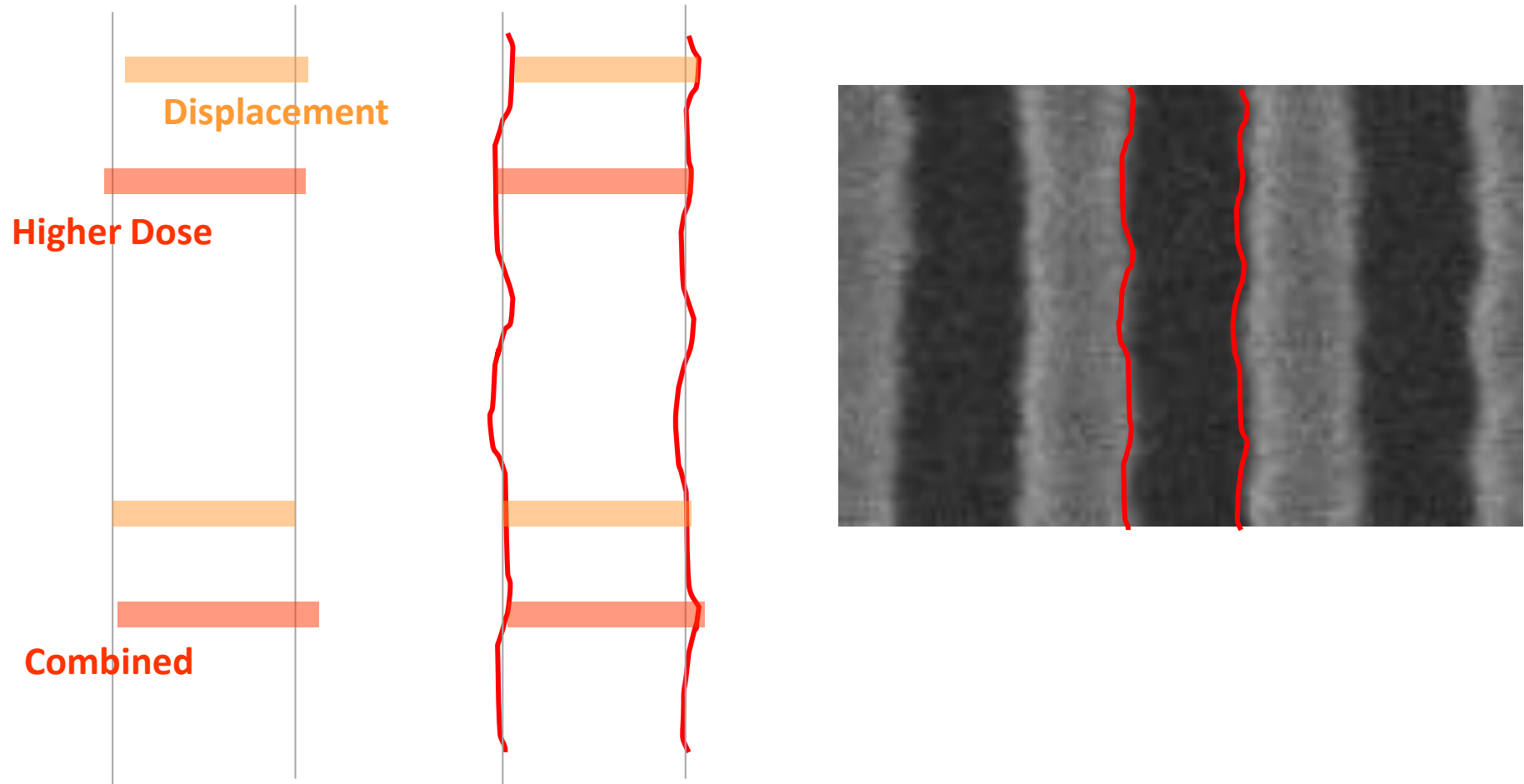
- Average-average plot

✓ **Post treatment**

- Ion implantation smoothing
- Vapor smoothing

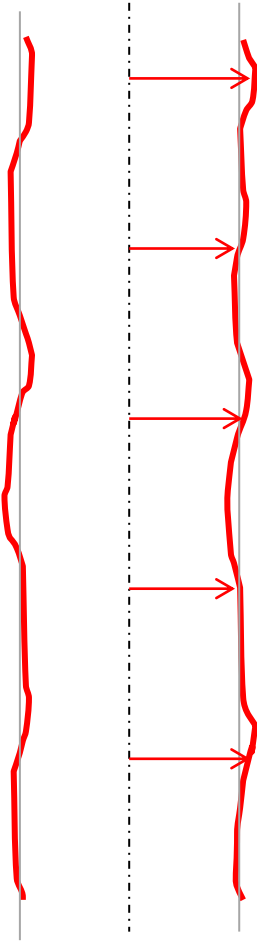
✓ **Summary**

Stochastic noise on Line Patterns



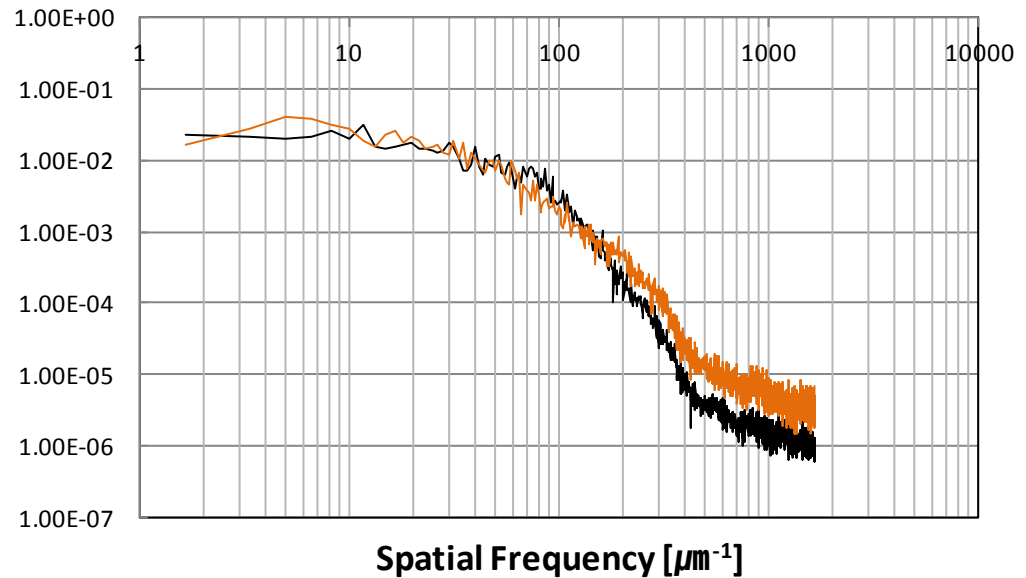
- For line patterns, stochastic noise is shown as roughness through dose & placement errors.

PSD analysis



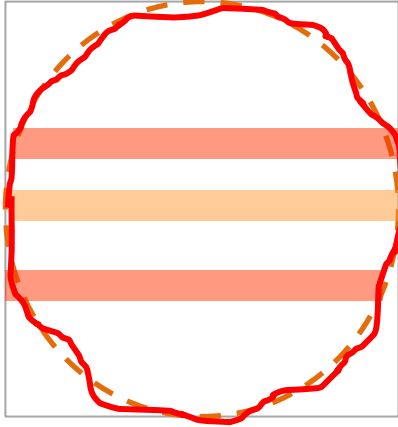
✓ ***Standard Deviation (3σ)***

✓ ***Power Spectral Density***



▪ **LER/LWR can be analyzed through spatial frequency by PSD.**

Stochastic noise on Hole Patterns



✓ ***CER (Contact Edge Roughness)***

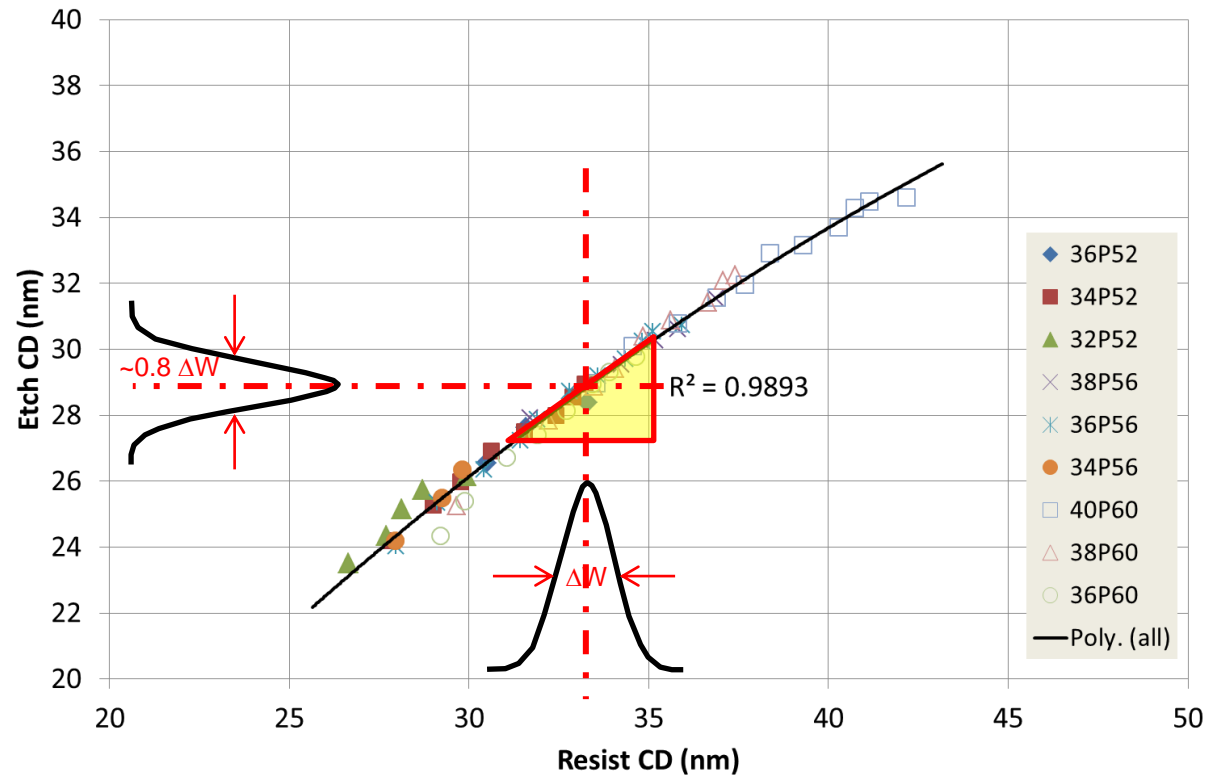
✓ ***CD uniformity***

$$LCDU = \sigma_{Repeating}^2 + \sigma_{Random}^2 + \sigma_{Metrology}^2$$

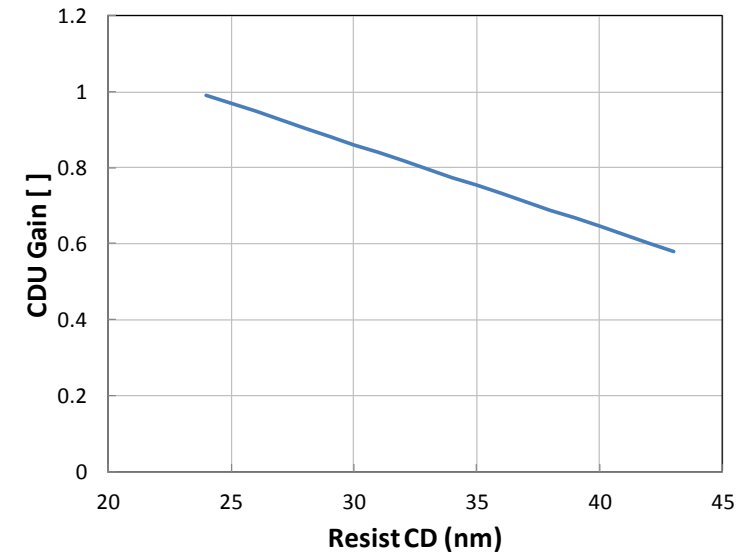
- CER is less related with electrical property.
- CD unif. measurement can be affected by mask CD unif. or measurement error without severe statistical approach.

Average-Average Plot

※ S.M. Kim, et al. (SPIE 2014)

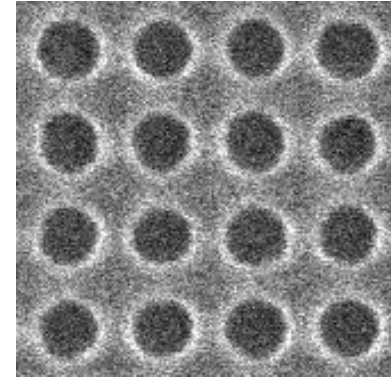
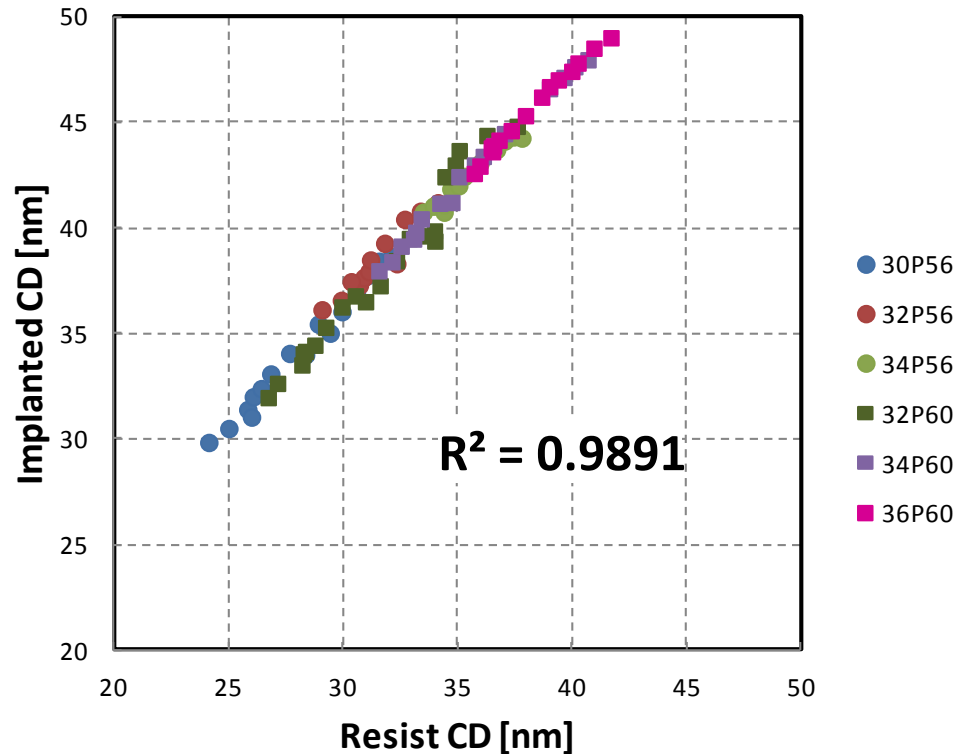


$$CDU\ Gain \equiv \frac{\partial (\text{Etch CD})}{\partial (\text{Resist CD})}$$



- Pitch doesn't affect on CD gain after etching, mask CD neither.
- CD unif. changes can be estimated by average CD's plot.

Ave.-Ave. Plot after Ion Implantation

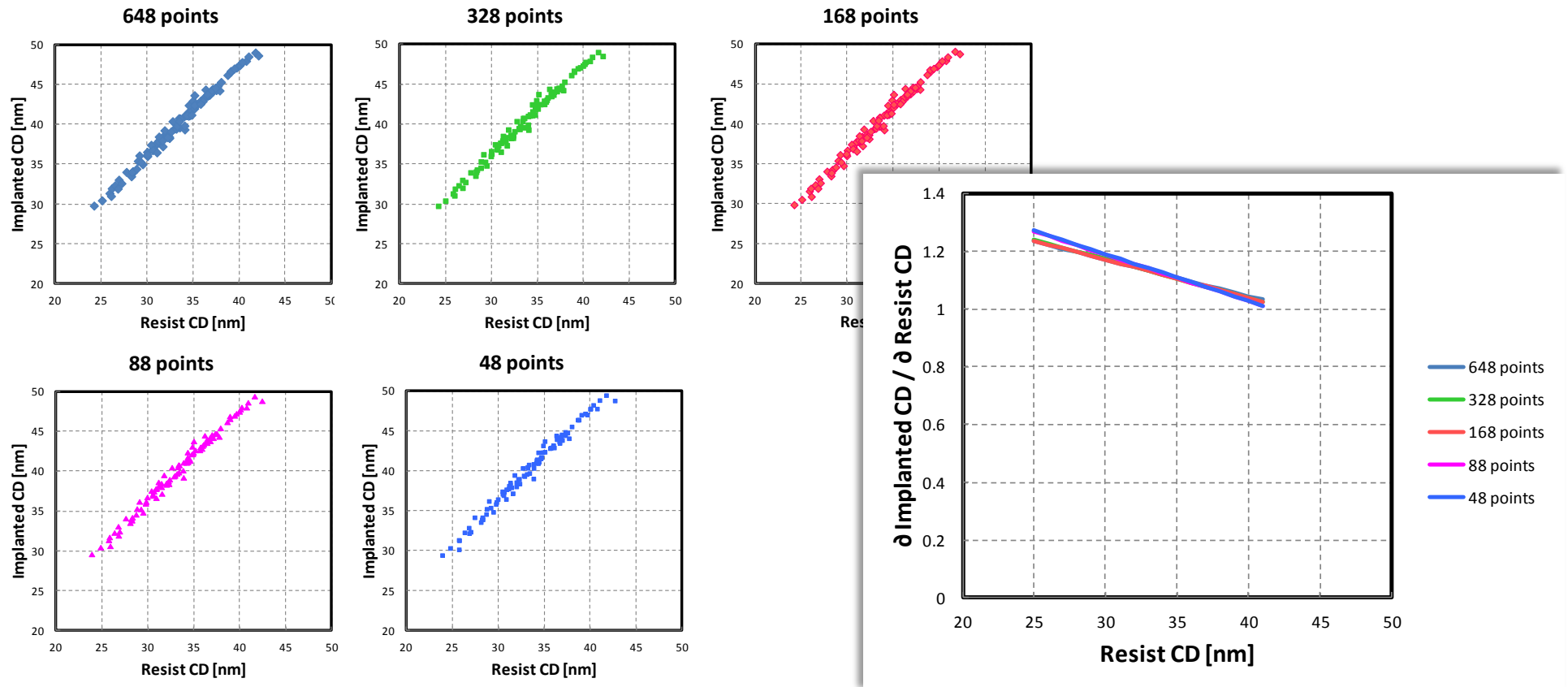


✓ *Resist Volume?*

✓ *Hole CD?*

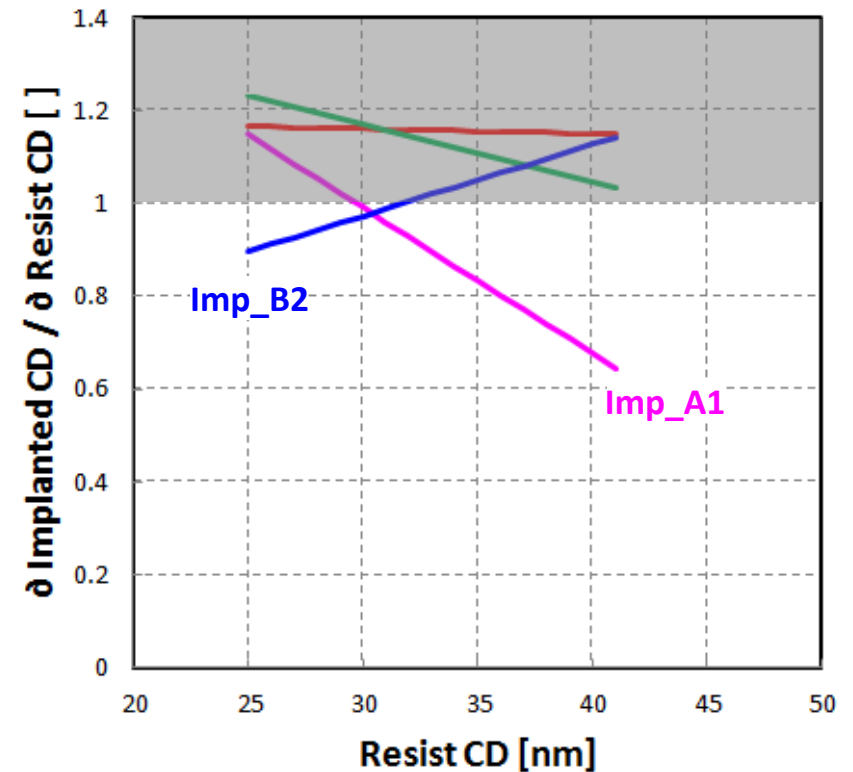
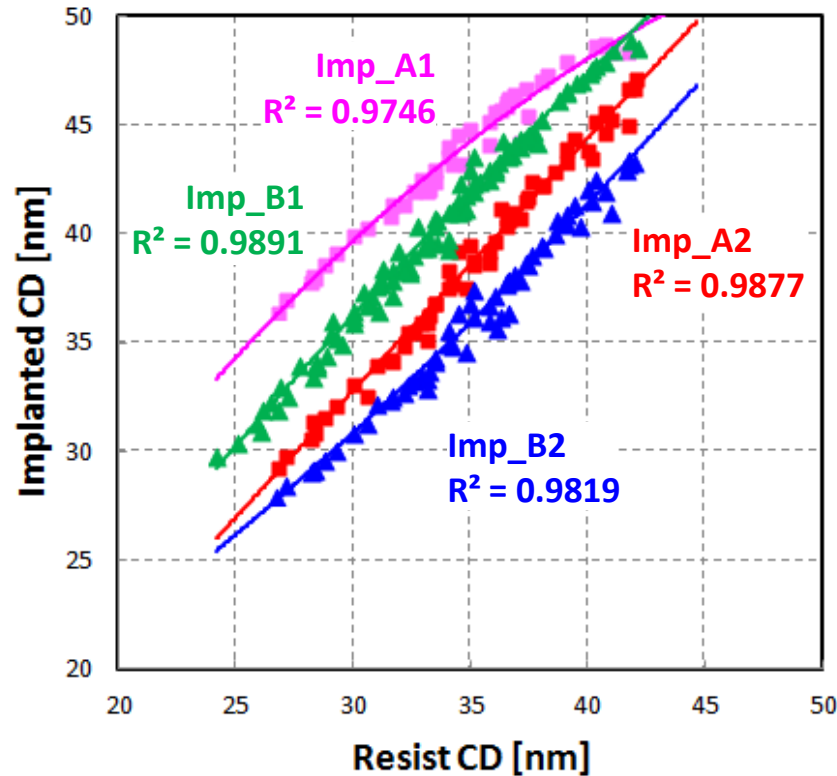
- Average CD after implantation fitted to one line regardless of pattern pitches and mask CD.

Number of Measurements



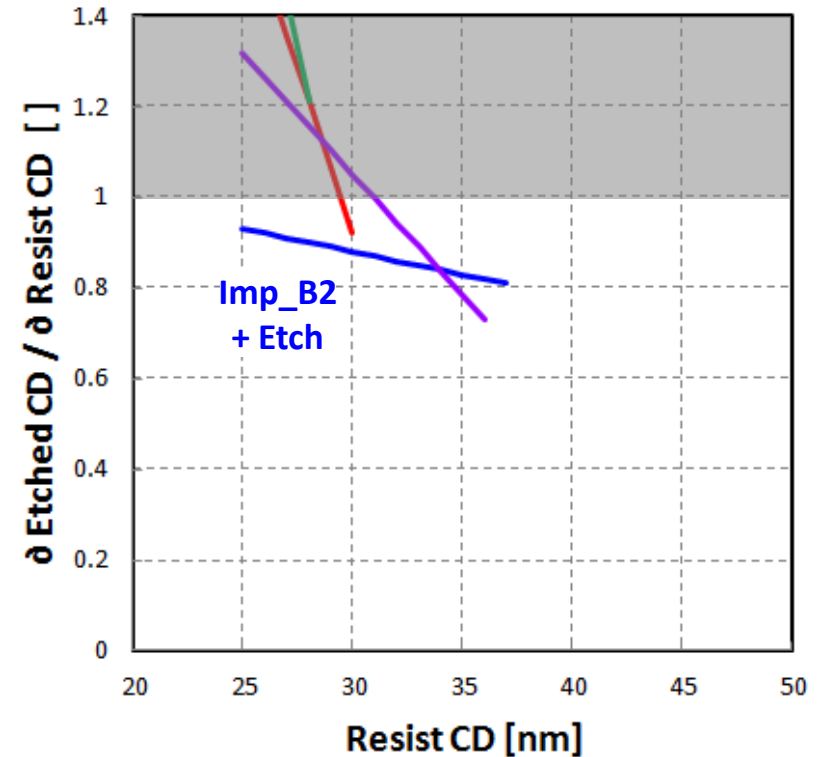
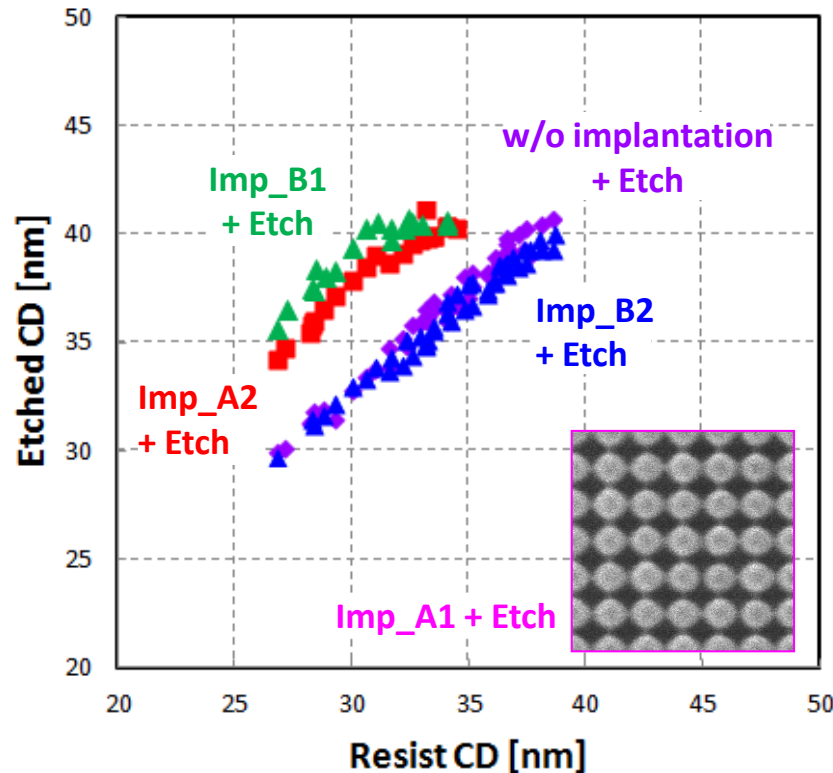
- Fit line not seriously affected by the number of measurements

Ion Implantations



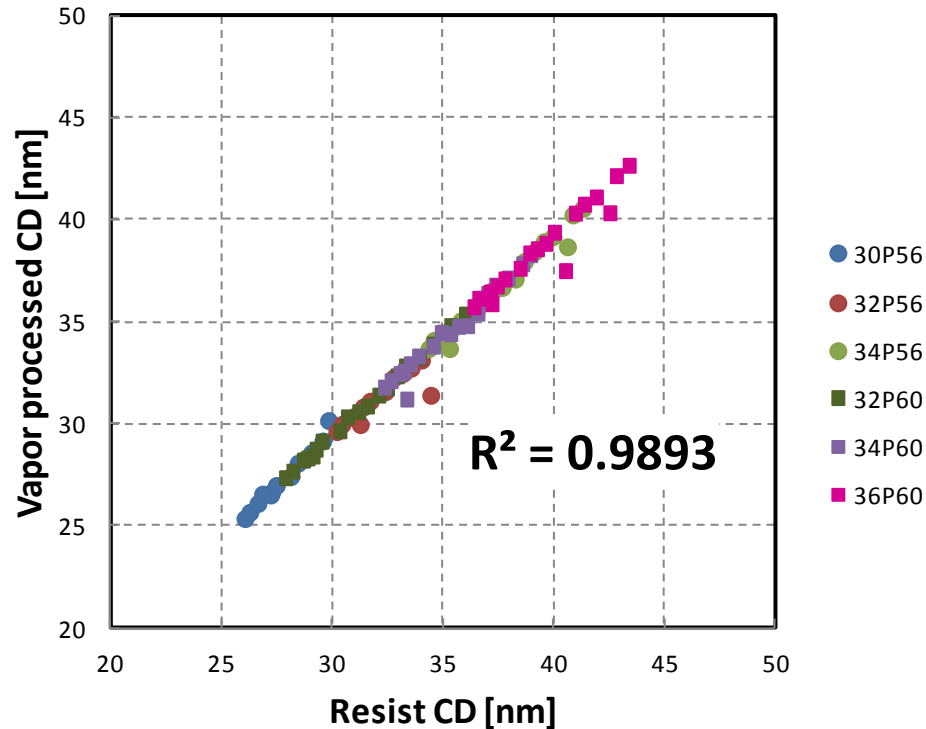
Possible improvements found in A1 & B2 conditions.

Implantation + Etching



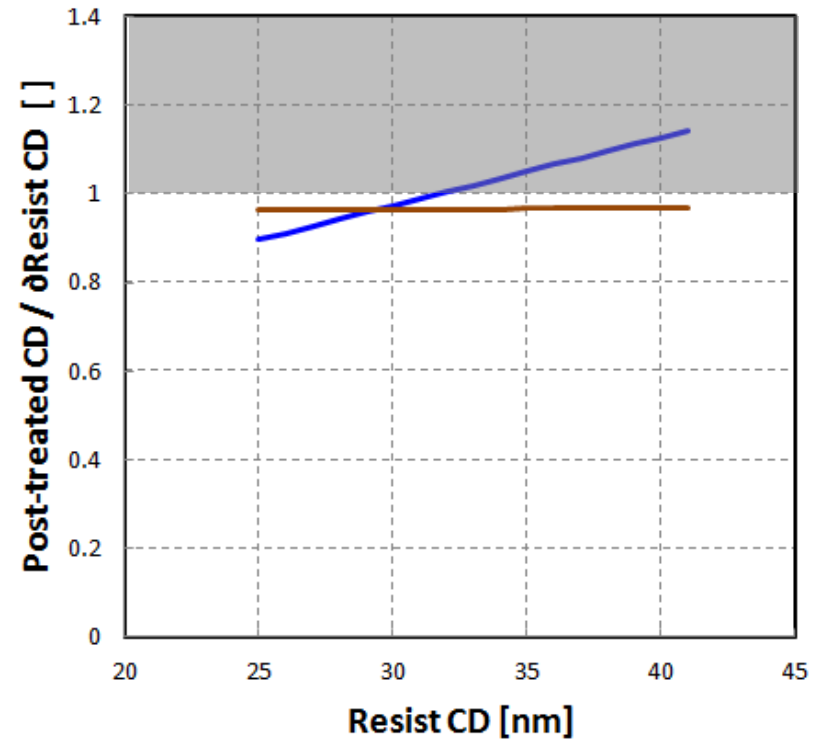
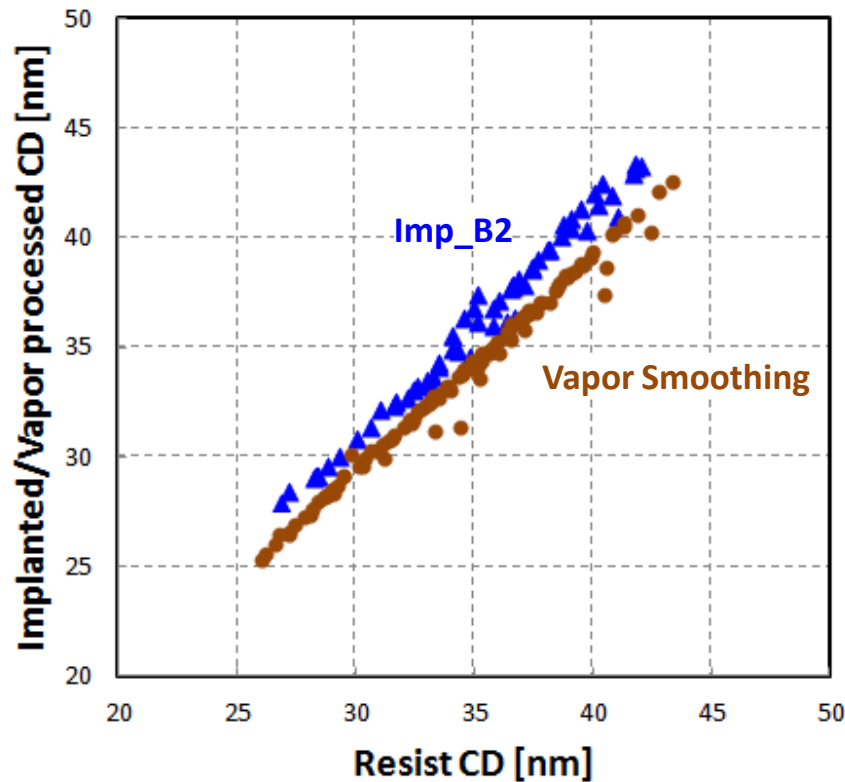
- Oxide wall penetrated in case of resist CD over 40nm
- Improved only at B2 condition after etching.

Ave.-Ave. Plot after Smoothing



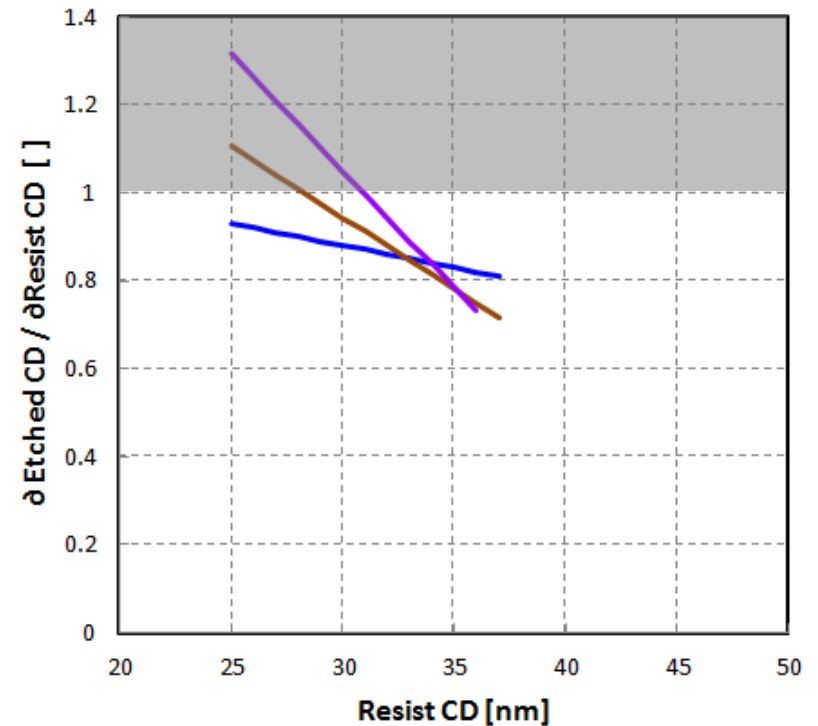
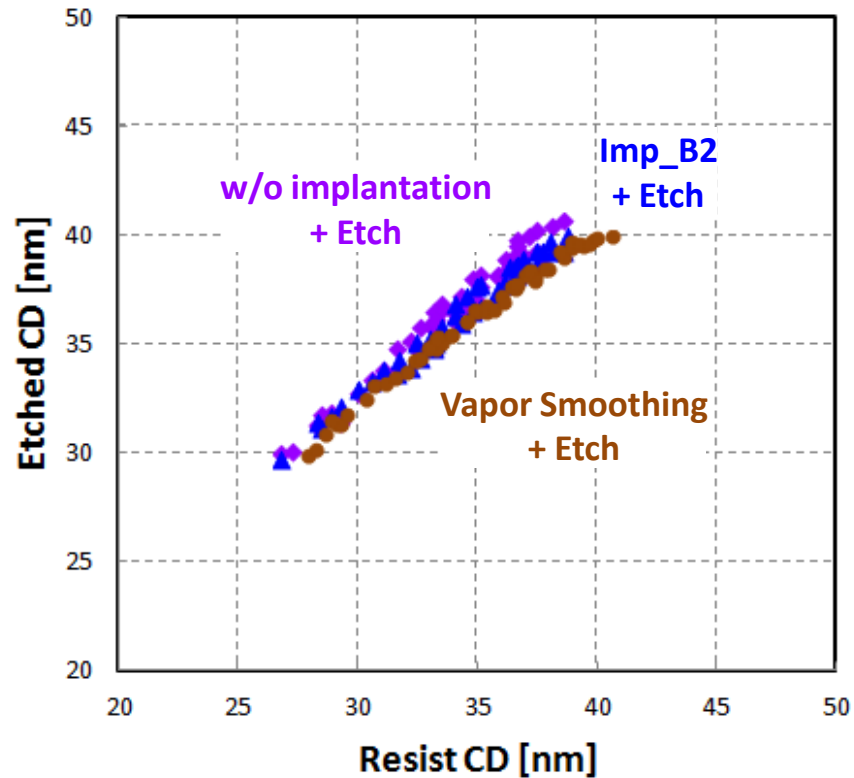
- Dependency on contact hole CD, not resist volume
: similarly with ion implantation process

Vapor Smoothing



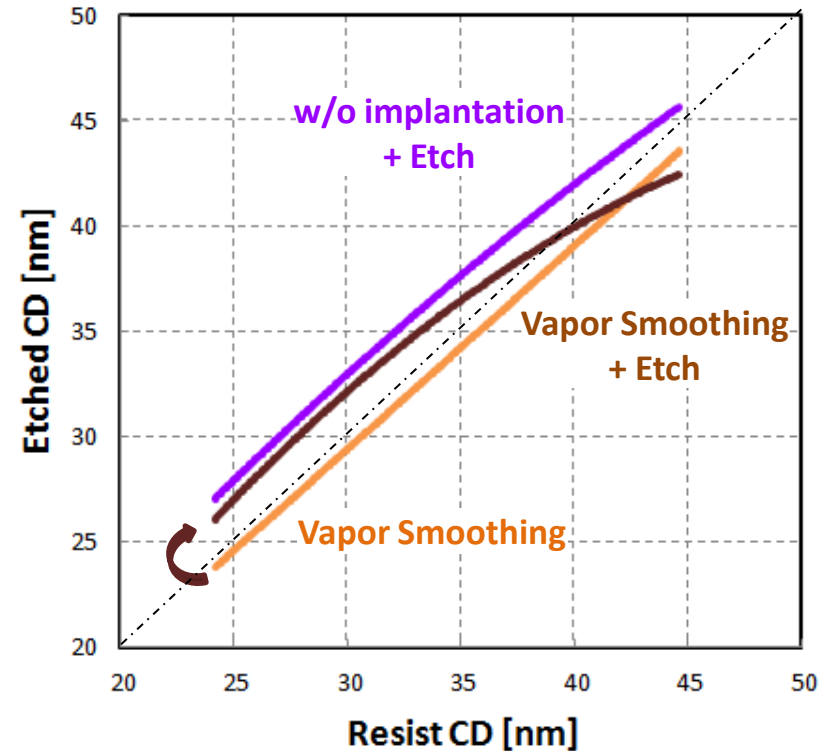
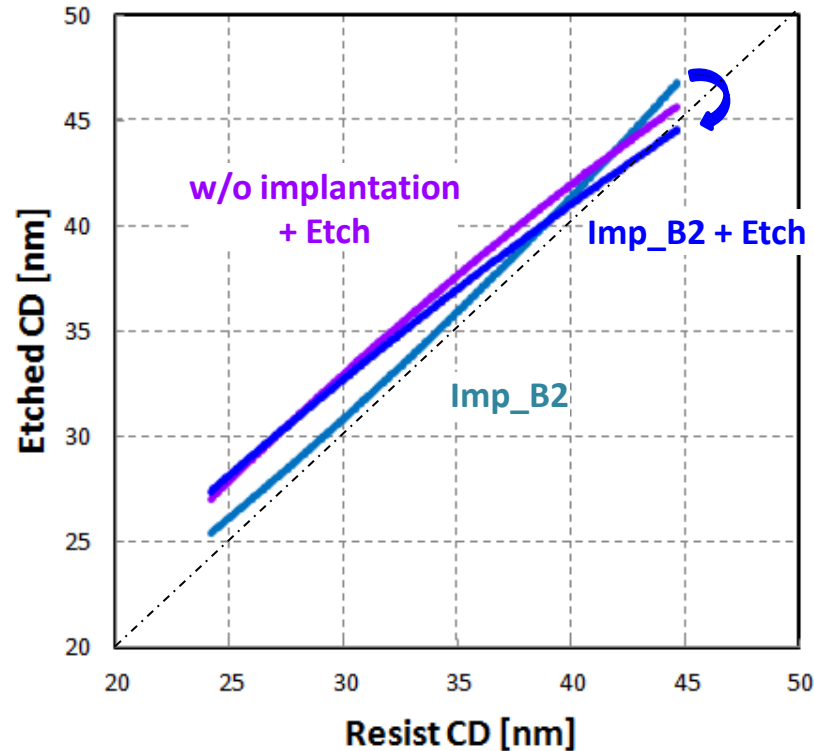
Small improvement, but constantly through resist CD

Vapor Smoothing + Etching



Improvement maintained after etching

Improvements by post-treatments



- Improved only in case of small CD changes
- Etching still more dominant in improvement

Summary

- ✓ Average-average plot be useful to investigate CD uniformity changes of contact hole patterns with stochastic noise.
- ✓ Ion implantation and vapor smoothing are insensitive to pattern pitches and mask CD, which means the effects doesn't come from volume change.
- ✓ Some implantation & vapor smoothing conditions are confirmed to improve CD uniformity, and better after etching.
 - : Process conditions should be optimized not to make resist CD over certain limit related with etching.

Acknowledgements

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Thank you